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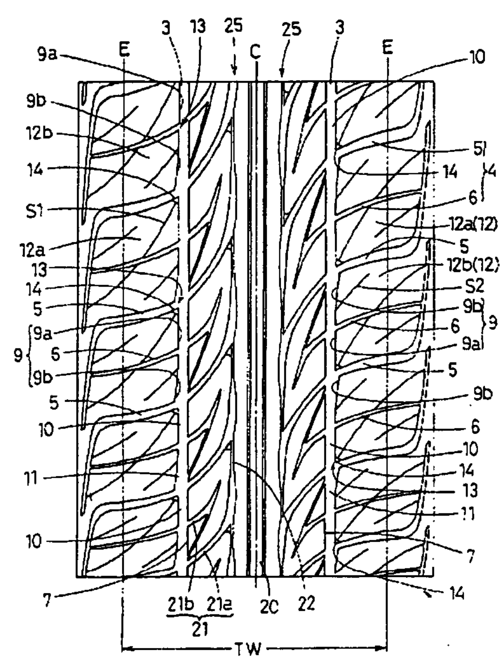
(54) **Pneumatic tyre**

(57) A pneumatic tyre (1) comprises a tread portion (2) provided between the tyre equator (C) and each tread edge (E) with a continuous main circumferential groove (3) and outer lateral grooves (5,6) including alternately arranged wide lateral grooves (5) and narrow lateral grooves (6) each extending axially outwardly from the main circumferential groove (3), the axially inner groove-wall (7) of the main circumferential groove (3) extending substantially straight in the circumferential direction, the axially outer groove-wall (9) of the main circumferential groove (3) comprising circumferential portions and inclined portions (9a,9b), the circumferential portions (9a), extending substantially straight so that the width of the main circumferential groove is substantially constant, and the inclined portions (9b) being inclined so that the width of the main circumferential groove increases from the narrow lateral grooves (6) to the wide lateral grooves (5).

Fig.1



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Description

[0001] The present invention relates to a pneumatic tyre, more particularly to a tread structure capable of improving wet performance and noise performance.

[0002] In order to improve wet performance of a tyre, the volume of circumferential grooves and lateral grooves in the tread portion may be increased, but so called air-tube resonance is liable to occur and so called pitch noise increases. The air-tube resonance is a resonance of air in a circumferential groove in the ground contacting patch of the tyre. The pitch noise is a noise generated by periodical contact of lateral grooves with a road surface.

[0003] Conventionally, to reduce pitch noise, the circumferential pitches of the lateral grooves are varied irregularly around the circumference of the tyre. However, to maintain the required resistance to uneven wear, provide good steering stability and the like, variation can not be so large. Thus, pitch noise reduction by pitch variation has its limit. As to the air-tube resonance noise, it can be reduced by decreasing the main circumferential groove width or employing a zigzag circumferential groove, but in either case the wet performance deteriorates. Therefore, based on a compromise between noise performance and wet performance, the widths and volumes of the circumferential grooves are determined.

[0004] It is therefore, an object of the present invention to provide a pneumatic tyre in which both the wet performance and noise performance are improved.

[0005] According to the present invention, a pneumatic tyre comprises a tread portion provided between the tyre equator and each tread edge with a circumferentially continuous main circumferential groove and circumferentially spaced outer lateral grooves, the outer lateral grooves including wide lateral grooves and narrow lateral grooves arranged alternately in the tyre circumferential direction, each said outer lateral groove extending axially outwardly from the main circumferential groove while inclining at a certain angle with respect to the circumferential direction of the tyre, the main circumferential groove having an axially inner groove-wall and an axially outer groove-wall, said axially inner groove-wall extending substantially straight in the circumferential direction, said axially outer groove-wall comprising circumferential portions and inclined portions each between the wide lateral grooves and narrow lateral grooves, said circumferential portions extending substantially straight in the circumferential direction so that the width of the main circumferential groove is substantially constant, and said inclined portions inclined so that the width of the main circumferential groove increases from the narrow lateral grooves to the wide lateral grooves, whereby the main circumferential groove has alternate constant width portions and widening portions.

[0006] Therefore, pitch noise is dispersed into a wider frequency range and improved owing to the alternate wide and narrow lateral grooves. The alternate constant width portions and widening portions prevent the occurrence of air resonance in the main circumferential groove and the air resonance noise is improved. Further, in the widening portions, as the width of the main circumferential groove increases from the narrow lateral grooves towards the wide lateral grooves, the drainage from the main circumferential groove to the wide lateral grooves is increased, and the wet performance, especially aquaplaning performance is improved.

[0007] An embodiment of the present invention will now be described in detail according to the accompanying drawings in which:

Fig.1 is a developed plan view of an embodiment of the present invention showing an example of the tread pattern;
Fig.2 shows the main circumferential groove and outer lateral grooves thereof;
Fig. 3 is a schematic cross sectional view showing the tread contour;
Fig.4 is a perspective view of the tread elements;
Fig.5 is a cross sectional view taken along a a sipe having open ends showing a variation of the depth thereof; and
Fig.6 is a cross sectional view taken along a sipe having an open end and closed end showing a variation of the depth thereof.

[0008] In the figures, a pneumatic tyre 1 according to the present invention comprises a tread portion 2 which is provided between the tyre equator C and each tread edge E with a main circumferential groove 3 extending continuously in the tyre circumferential direction, and a plurality of circumferentially spaced outer lateral grooves 4 each of which extends axially outwardly from the main circumferential groove 3 and inclines at an angle θ with respect to the circumferential direction of the tyre (see Fig. 2).

[0009] In this embodiment, the pneumatic tyre has a size 185/65R14 for passenger cars. The tread portion 2 is provided with a bi-directional tread pattern which is substantially symmetrical about a point on the tyre equator C if the pitch variation is ignored.

[0010] Here, the tread edge E is one of the axial outermost edges of the ground contacting region under a standard loaded condition in which the tyre is mounted on a standard wheel rim and inflated to a standard pressure and loaded with a standard tyre load. The standard rim is the "standard rim" specified in JATMA, the "Measuring Rim" in ETRTO, the "Design Rim" in TRA or the like. The standard pressure is the "maximum air pressure" in JATMA, the "Inflation

Pressure" in ETRTO, the maximum pressure given in the "Tyre Load Limits at Various Cold Inflation Pressures" table in TRA or the like. In the case of passenger car tyres, however, 180 kPa is used as the standard pressure. The standard load is the "maximum load capacity" in JATMA, the "Load Capacity" in ETRTO, the maximum value given in the above-mentioned table in TRA or the like.

[0011] The main circumferential groove 3 is a substantially straight groove extending continuously in the tyre circumferential direction. In this example, it is disposed at a substantially middle position between the tyre equator C and the tread edge E.

[0012] The main circumferential groove 3 has a width GW in a range of from 1 to 6 %, preferably 1.2 to 5 % of the ground contacting width TW between the tread edges E, and a depth GD in a range of from 4 to 8 %, preferably 4 to 6 % of the ground contacting width TW. It is however not always necessary to set the width GW and depth GD in these ranges.

[0013] The outer lateral grooves 4 include wide lateral grooves 5 and narrow lateral grooves 6 which are arranged alternately in the circumferential direction. The wide lateral grooves 5 and narrow lateral grooves 6 each extend from the main circumferential groove 3 to the tread edge E and are open at the tread edge E.

[0014] Here, the "wide" lateral groove and "narrow" lateral groove mean that the average width gwla of the wide lateral groove 5 is more than the average width gw2a of the narrow lateral groove 6. The average width means a groove width gwl, gw2 measured at a right angle to the groove centre line and averaged between the main circumferential groove 3 and the tread edge E.

[0015] In this example, the width gwl of the wide lateral groove 5 is less than the width GW of the main circumferential groove 3. But the depth of the wide lateral groove 5 is the substantially same as that of the main circumferential groove 3.

[0016] The average width gw2a of the narrow lateral groove 6 is set in a range of more than 1.0 mm, preferably more than 1.8 mm.

[0017] The average width ratio (gwla/gw2a) is more than 1.0 as explained above, but it is preferably set in a range of from 1.20 to 3.50, more preferably 2.0 to 3.0 to disperse the frequency spectrum of the pitch noise and thereby to improve the noise performance.

[0018] In the region between the main circumferential groove 3 and each tread edge E, the outer lateral grooves 4 have an inclination angle θ of from 50 to 85 degrees, preferably 65 to 85 degrees with respect to the circumferential direction. In this region, the inclination angle 0 can be constant, but in this example, it gradually increases from the groove 3 to the tread edge E. If the inclination angle 0 is less than 50 degrees, wear resistance of tread elements 12 and steering stability are liable to become worse. If the inclination angle θ is more 85 degrees, drainage from the main circumferential groove 3 tends to decrease.

[0019] As a result of the alternate wide lateral grooves 5 and narrow lateral grooves 6 the pitch noise is reduced. By combining this with a pitch variation the noise reduction can be further enhanced.

[0020] The main circumferential groove 3 has, as shown in Fig.2, an axially inner groove-wall 7 which extends substantially along a circumferential straight line.

[0021] On the other hand, the axially outer groove-wall 9 thereof comprises alternate circumferential portions 9a and inclined portions 9b, each defined between the circumferentially adjacent wide lateral groove 5 and narrow lateral groove 6. The circumferential portions 9a extend in parallel with the longitudinal direction of the main circumferential groove 3 or the circumferential direction, whereby the width of the main circumferential groove 3 is constant in these portions (constant width portion). The inclined portions 9b are inclined axially outwardly from the narrow lateral groove 6 to the wide lateral grooves 5, whereby the width of the main circumferential groove 3 gradually increases from the narrow lateral groove 6 to the wide lateral grooves 5 (widening portion). At the axially inner end of each narrow lateral groove 6, the end of the inclined portion 9b and the end of the circumferential portion 9a are positioned at the substantially same axial position.

[0022] Preferably, the ratio (Gw2M/Gw1) of the maximum groove width Gw2M in the widening portion 11 of the main groove 3 to the groove width Gwl in the constant width portion 10 of the main groove 3 is set in a range of from 1.10 to 2.0, more preferably from 1.25 to 1.45, whereby the air-tube resonance in the main circumferential groove 3 can be prevented although it is a straight groove.

[0023] In this example, each inclined portion 9b is slightly convexly curved. However, various configurations, e.g. straight, concave, zigzag, wavy and the like may be used.

[0024] The inclining directions of the inclined portions 9b are such that the inclined portions intersect the respective wide lateral grooves 5 at obtuse angles. In other words, the inclined portions 9b and the outer lateral grooves 4 are inclined towards the same directions Therefore, flow of water from the main groove 3 to the wide lateral grooves 5 is improved and as a result wet performance is improved.

[0025] Further, as shown in Fig.4, acute angled corners 13 formed between the wide lateral grooves 5 and the constant width portions 10 of the main groove 3 are cut-out by a substantially flat triangular plane 14. The width L of the triangular plane 14 at the ground contacting surface 16 is preferably set in a range of from 2.0 to 6.0 mm, more preferably 4.0 to 5.0 mm. The triangular plane 14, as seen in Fig. 4, is sloped toward the groove bottom, and the radially

inner end thereof reaches to a depth (h) in a range of from 50 to 100 %, preferably 80 to 90 % of the height H of the tread element 12a or the groove depth H.

[0026] Such a corner cut 14 can be also provided for acute angled corners formed between the narrow lateral grooves 6 and the widening portions 11 of the main groove 3.

[0027] The corner cuts 14 further improve the water flow from the main circumferential groove to the lateral grooves, and help to reduce the air-tube resonance in the main circumferential groove, and further can prevent the tread rubber from tearing off.

[0028] In order to adjust the tread rigidity to improve ride comfort, the tread portion 2 can be provided with sipes having a width of less than 1.5 mm, usually less than 1 mm. In this embodiment, two types of sipes S1 and S2 are provided. Sipe SI has two open ends. Sipe S2 has an open end and a closed end.

[0029] As shown in Fig.1, shoulder blocks 12a with a corner cut are each provided with a sipe S1 which starts from the cut-off corner 14 which extends across the block 12a, while inclining toward the same direction as of the outer lateral grooves 4, and reaches to the adjacent narrow lateral groove 6 to open thereto. Thus, both the ends thereof are opened to the grooves. The inclination angle θs (see Fig. 4) of the sipe S1 is set in a range of from 10 to 50 degrees, preferably 20 to 40 degrees with respect to the circumferential direction so as to be 25 to 65 degrees smaller than the inclination angle θ of the lateral grooves. The sipe SI may have a constant depth but, in order to improve the resistance to wear especially uneven wear such as heel & toe wear, the depth is gradually decreased towards its open ends or towards the lateral grooves as shown in Fig.5. For example, the sipe SI has a minimum depth of 1 mm at its open ends at the lateral grooves and a maximum depth of 5 mm between the ends. Each of the sipes S1 has an extension into the next shoulder block 12b which extends beyond the tread edge E. This extension is also of the S1-type, that is, both ends are opened.

[0030] Each of the shoulder blocks 12b is provided with a sipe S2 which starts from the middle part of the inclined portion 9b and ends within this block 12b. Thus, each sipe S2 has an open end and a closed end. As shown in Fig.6, the sipe S2 is also provided with a variable depth which gradually decreases from the closed end to the open end.

[0031] As to the central region of the tread portion 2 between the two main circumferential grooves 3, in this embodiment, there are provided a central main circumferential groove 20 extending continuously in the circumferential direction along the tyre equator C and axially inner lateral grooves 21 extending axially inwardly from the main circumferential grooves 3.

[0032] The inner lateral grooves 21 include first inner lateral grooves 21a each extending as an extension of one of the wide lateral grooves 5, and second inner lateral grooves 21b each extending as an extension of one of the narrow lateral grooves 6, wherein the average width of the first grooves 21a is more than the average width of the second grooves 21b, and the first grooves 21a and second grooves 21b are arranged alternately in the circumferential direction.

[0033] The first inner lateral grooves 21a extend axially inwards, but do not connect with the central main circumferential groove 20.

[0034] The first inner lateral grooves 21a are curved such that the inclination thereof gradually decreases as they approach to the central main circumferential groove 20, and finally they become substantially parallel to the circumferential direction. These parallel portions are aligned and connected with each other by narrower straight circumferential grooves 22. As a result, between the central circumferential groove 20 and each of the main circumferential grooves 3, a groove 25 extending continuously in the circumferential direction along a straight line is formed. Therefor, in this resultant groove 25, due to the narrower grooves 22, the groove width changes along its length and the occurrence of air tube resonance can be prevented.

[0035] The second inner lateral grooves 21b extend axially inwardly from the main circumferential groove 3, while inclining towards the same direction as the other lateral grooves, but end at the middle point between the main circumferential groove 3 and central groove 20. With respect to the circumferential direction, the inclination angle thereof gradually decreases towards the axially inner end. From a middle point between the axially inner end and outer end, a narrower branch groove extends, in a direction reverse to that of an axially inner groove part between the above-mentioned inner groove end and branching point, to the main groove 3 near the intersecting point of the wide lateral groove 5 and main groove 3.

[0036] The above explained tread pattern is bi-directional, but it is also possible to provide a uni-directional tread pattern. Such a uni-directional tread pattern can be made based on the above explained bi-directional tread pattern, for example, by modifying one half on one side of the tyre equator C to become symmetrical about the tyre equator C and then circumferentially shifting the phase of one half from the other one half to remove periodicity.

Comparison Tests

[0037] Radial tyres having the same structure except for the tread pattern were made and tested for the aquaplaning performance, noise performance, ride comfort and wear resistance, using a 1800cc Japanese passenger car provided on all four wheels with test tyres inflated to 200 kPa. The tyre size was 185/65R14 and the rim size was 5-1/2 JJ X14.

The test tyres had the same carcass structure composed of a single ply of polyester cords arranged radially at an angle of 88 degrees with respect to the tyre equator, and the same belt structure composed of two crossed breaker plies. A reference tyre was used which had a tread pattern similar to the tread pattern shown in Fig.1 but the width of the main circumferential grooves 3 constant along the length thereof.

Aquaplaning performance test:

[0038] On a 100m-radius asphalt-surfaced course provided with a 10mm deep and 20m long water pool, lateral acceleration (lateral G) was measured on the front wheel, gradually increasing the approaching speed, to obtain the average lateral G from 50 km/h to 80 km/h. The results are indicated in Table 1 by an index based on the Ref. tyre as 100. The larger the value, the better the performance.

Noise performance test:

[0039] During running the car on an even asphalt-surfaced road at a speed of 60 km/h, the pattern noise was evaluated by the test driver. The results are indicated in Table 1 by an index based on the Ref. tyre as 100. The smaller the value, the better the pattern noise.

Ride comfort test:

[0040] During running the car on uneven roads including a rough asphalt road, a stone-paved road and a gravelled road, the test driver evaluated the ride comfort from harshness, thrust, damping etc. The results are indicated in Table 1 by an index based on the Ref. tyre being 100. The larger the value, the better the ride comfort.

Wear resistance test:

[0041] During running the car for 500 km at a speed of 100 km/h, a braking deceleration of 0.45G was applied four times per 3 km. Then, the difference of wear at the circumferential, ends (namely heel and toe edges) of the shoulder blocks 12a from that in the middle thereof was measured. The results are indicated in Table 1 by an index based on the Ref. tyre being 100. The larger the value, the better the wear resistance.

Table 1

Tyre	Ref.	Ex.1	Ex.2	Ex.3	Ex.4	Ex.5	Ex.6	Ex.7	Ex.8
Lateral groove									
Wide groove									
av. width gw1a (mm)	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
av. angle θ (deg.)	77	77	77	77	77	77	77	77	77
Narrow groove									
av. width gw2a (mm)	2.8	2.8	2.8	2.8	2.8	1.7	2.8	2.8	2.8
av. angle θ (deg.)	77	77	77	77	77	77	77	77	77
gw1a/gw2a	1.5	1.5	1.5	1.5	1.5	2.5	1.5	1.5	1.5
Main circumferential groove									
Constant width portion									
Groove width GW1 (mm)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Widening portions									
Max. groove width GW2M (mm)	5.6	8.4	6.2	11.2	7.6	8.4	8.4	8.4	8.4
GW2M/GW1	1	1.5	1.1	2	1.35	1.5	1.5	1.5	1.5
Corner cut									
h/H	0	0	0	0	0	0	0	0	0.88
L(mm)	0	0	0	0	0	0	0	0	5

Table 1 (continued)

Tyre	Ref.	Ex.1	Ex.2	Ex.3	Ex.4	Ex.5	Ex.6	Ex.7	Ex.8
Corner cut									
Sipes S1 Depth (mm)	 0	 0	 0	 0	 0	 0	*1 5	*2 1-3	 0
Test results									
Aquaplaning performance	100	105	102	107	105	105	105	105	106
Noise performance	100	99	100	98	100	102	100	100	100
Ride comfort	100	100	100	100	100	100	102	102	100
Wear resistance	100	102	100	105	102	102	98	100	103

*1) Constant depth
*2) Variable depth shown in Fig.5

[0042] As can be seen the tyres of the invention meet the objectives of the invention

Claims

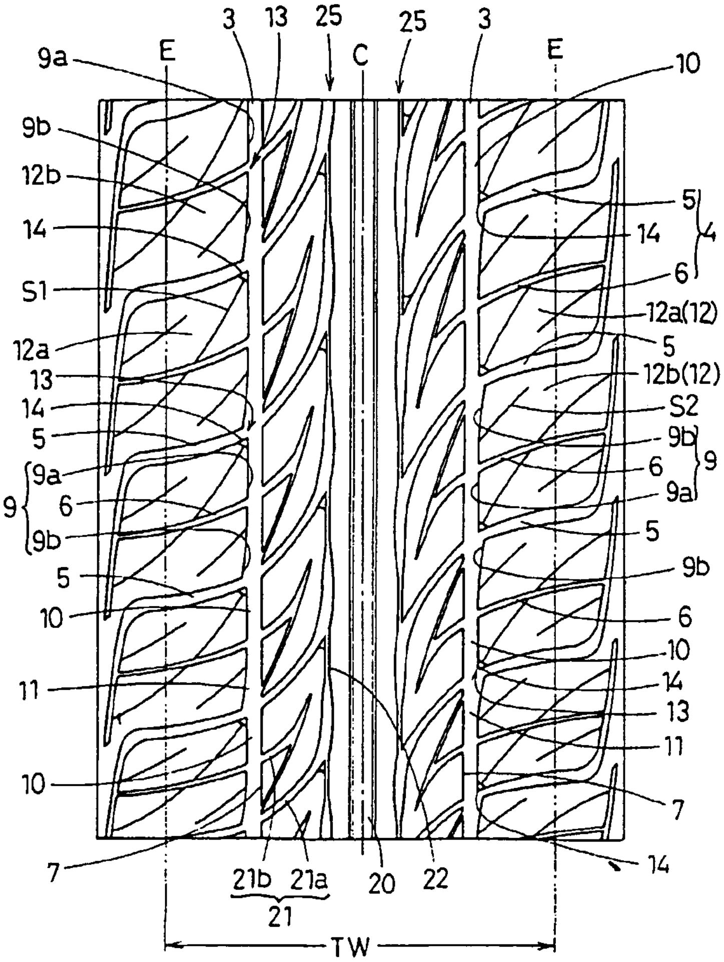
1. A pneumatic tyre (1) comprising a tread portion (2) provided between the tyre equator (C) and each tread edge (E) with a circumferentially continuous main circumferential groove (3) and circumferentially spaced outer lateral grooves (4), characterised in that said outer lateral grooves (4) include wide lateral grooves (5) and narrow lateral grooves (6) alternately arranged in the tyre circumferential direction, each extending axially outwardly from the main circumferential groove (3) while inclining at a certain angle (θ) with respect to the circumferential direction of the tyre, said main circumferential groove (3) having an axially inner groove-wall (7) and an axially outer groove-wall (9), said axially inner groove-wall (7) extending substantially straight in the circumferential direction, said axially outer groove-wall (9) comprising circumferential portions (9a) and inclined portions (9b) each between the wide lateral grooves (5) and narrow lateral grooves (6), the circumferential portions (9a) extending substantially straight in the circumferential direction so that the width (Gwl) of the main circumferential groove (3) is substantially constant, and the inclined portions (9b) inclined so that the width (Gw2) of the main circumferential groove increases from the narrow lateral grooves (6) to the wide lateral grooves (5), whereby the main circumferential groove (3) has alternate constant width portions and widening portions.

2. A pneumatic tyre according to claim 1, characterised in that the widening portions (9b) have a maximum groove width (Gw2M) in a range of from 1.10 to 2.0 times a groove width (Gwl) of the constant width portions, and the average groove width (gw1a) of the wide lateral grooves (5) is in a range of from 1.20 to 3.50 times the average groove width (gw2a) of the narrow lateral grooves (6).

3. A pneumatic tyre according to claim 1 or 2, characterised in that on each side of the tyre equator (C), the inclined portions (9b) and the lateral grooves (5,6) are inclined toward the same direction, and corners (13) between the constant width portions (10) of the main circumferential groove (3) and the wide lateral grooves (5) are cut-off.

4. A pneumatic tyre according to claim 3, characterised in that the tread portion is provided with sipes each extending from one of the cut-off corners (13), while inclining toward the same direction as of the lateral grooves (5,6), to the adjacent narrow lateral groove (6).

Fig.1



9a
E
3
13
25
C
25
3
E
10
9b
12b
14
S1
12a
13
14
5
9
9a
6
9b
5
10
11
10
7
5
14
4
6
12a(12)
5
12b(12)
S2
9b
9
6
9a
5
9b
6
10
14
13
11
7
14
21b
21a
21
20
22
TW

Fig.2

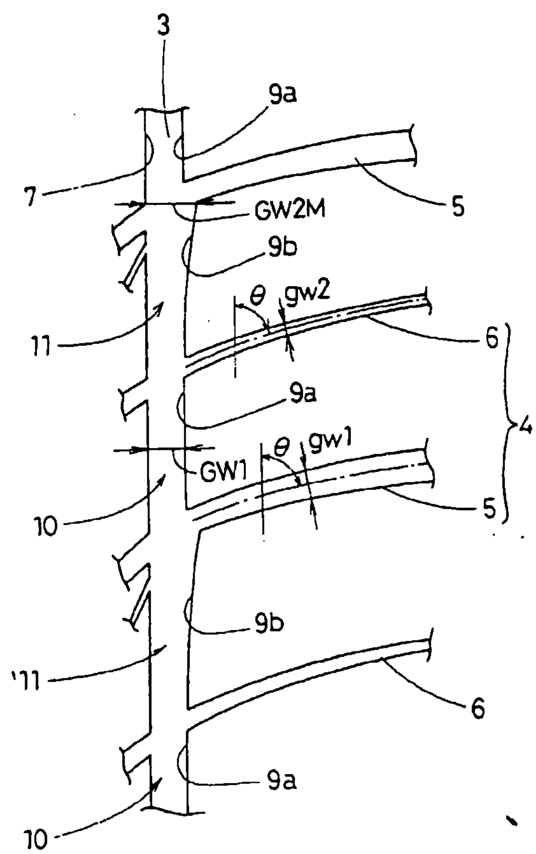


Fig.3

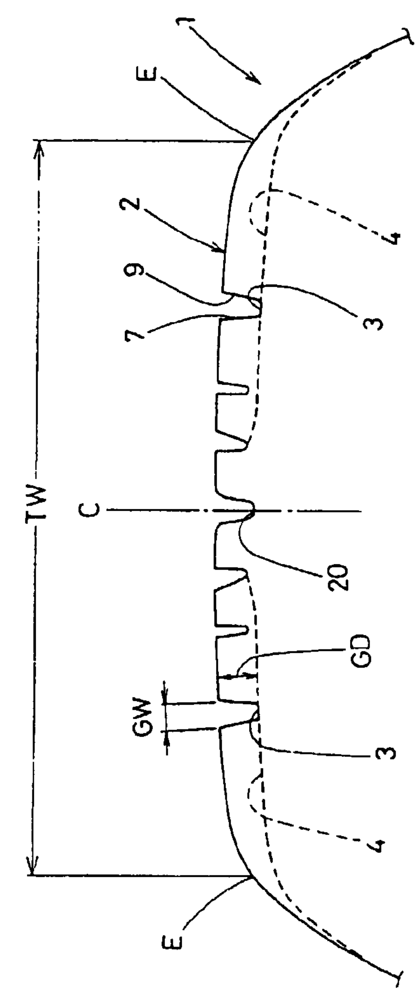


Fig.4

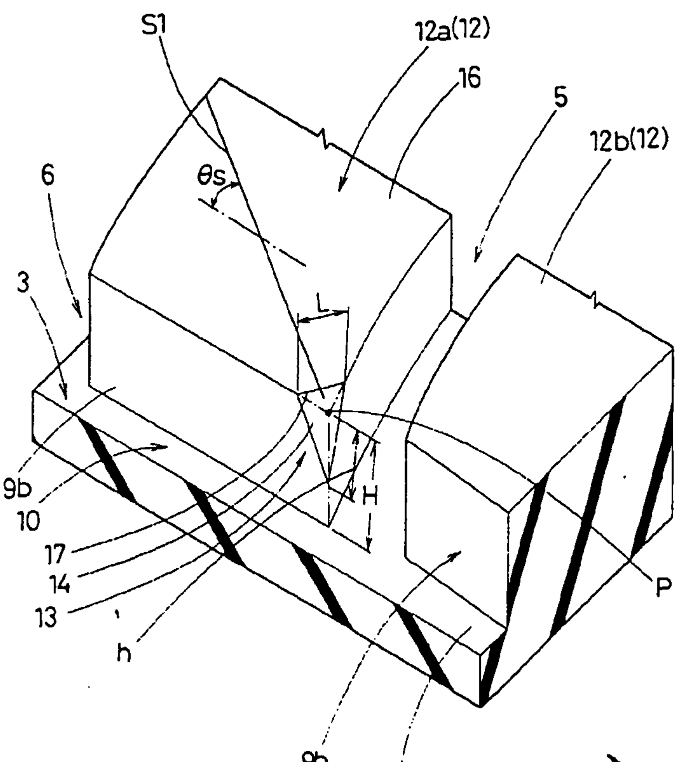


Fig.5

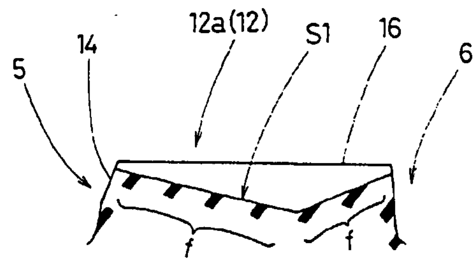


Fig.6